AL.2.1993-328
C.2

LOT DRAINAGE CHARACTERISTICS STUDY
SANDY SOILS

CANADIANA

AUG
AOUT 24 1993

Alberta
MUNICIPAL AFFAIRS
Housing Division

[redacted]

LOT DRAINAGE CHARACTERISTICS STUDY
SANDY SOILS

September 1992

Prepared by:

CH2M Hill Engineering Ltd.

The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

With funding provided by
Alberta Municipal Affairs

ISBN: 0-88654-390-8

Printed on Recycled Paper

FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Program is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

The Program offers assistance to builders, developers, consulting firms, professionals, industry groups, building products manufacturers, municipal governments, educational institutions, non-profit groups and individuals. At this time, priority areas for investigation include building design, construction technology, energy conservation, site and subdivision design, site servicing technology, residential building product development or improvement and information technology.

As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied. Comments and suggestions on this report are welcome. Please send comments or requests for further information to:

Innovative Housing Grants Program
Alberta Municipal Affairs
Housing Programs Division
Research and Technical Support
16th Floor, CityCentre
10155 - 102 Street
Edmonton, Alberta
T5J 4L4

Telephone: (403) 427-8150

Digitized by the Internet Archive
in 2015

https://archive.org/details/lotdrainagechara00ch2m_1

ACKNOWLEDGEMENTS

We would like to thank the following agencies for providing funding and support for this project:

Alberta Municipal Affairs

The City of Edmonton

Strathcona County

Alberta New Home Warranty Program

This project would not have been possible without the assistance and cooperation of the Strathcona County Public Works staff.

TABLE OF CONTENTS

Page No.

LIST OF PHOTOGRAPHS ii
LIST OF FIGURES iii
EXECUTIVE SUMMARY iv
GLOSSARY OF TERMS vi

1.0 INTRODUCTION 1
  1.1 Objectives 1
  1.2 Project Scope 2
  1.3 Description of Research Method 4
  1.4 Organization of Document 5

2.0 SITE DESCRIPTION AND TEST APPROACH 6
  2.1 Test Site Description 6
  2.2 Test Approach 9

3.0 TEST RESULTS AND ANALYSIS 20
  3.1 Data Interpretation 20
  3.2 Ground Cover 27
  3.3 Grading of Backfill Zone 28
  3.4 Roof Leader Location 30
  3.5 Groundwater Response 30
  3.6 Evaluation of Test Results 30

4.0 CONCLUSIONS AND RECOMMENDATIONS 34
  4.1 Conclusions 34
  4.2 Recommendations 34

Appendix A - Sample Field Data Sheets

LIST OF PHOTOGRAPHS

Page No.

PHOTO 1: Research Facility Site 6
PHOTO 2: Site Work Completed 7
PHOTO 3: Impermeable Geomembrane 9
PHOTO 4: Piezometers 17
PHOTO 5: Raingauge 17
PHOTO 6: Water Level Recorder 18
PHOTO 7: On/Off Current Sensor 18
PHOTO 8: Infiltrometer 19
PHOTO 9: Rainfall Simulation Manifold 19

LIST OF FIGURES

Page No.

FIGURE 1: Lot Drainage Characteristics Study Initial Schedule 3

FIGURE 2: Foundation Drain & Sump Plan 8

FIGURE 3: Flowrate Calculations for Storm Events 12

FIGURE 4: 4-Hour 5-Year Design Storm 13

FIGURE 5: 24-Hour 5-Year Design Storm 14

FIGURE 6: Dates of Field Testing 15

FIGURE 7: Summary of Simulations 21

FIGURE 8: September 23, 1991 Total Lot 24

FIGURE 9: September 23, 1991 Back-Lot 25

FIGURE 10: September 23, 1991 Front Lot 26

FIGURE 11: Comparison of Hydrograph Shapes 29

FIGURE 12: Test Results In Descending Order of Peak Recorded Foundation Drain Flow 31

FIGURE 13: Storm Event Comparison 33

FIGURE 14: Recommended Grading and Backfill Procedure 36
If Sand is Used as Backfill

EXECUTIVE SUMMARY

Foundation drain systems around residential basements contribute significant flow into the sanitary sewers to which they are connected. This flow can, and frequently does, cause sewer overloading, surcharging, and basement flooding. Where foundation drains are connected to combined sewers, the resulting flows can increase the frequency and duration of combined sewer overflows. This can result in extra capital and operating costs for collection of the effluent and for treatment facilities.

This project examined the extent to which different lot drainage characteristics affect foundation drain flow in sandy soils. From previous research lot grading, backfill practice, ground cover, and roof leader discharge locations were identified as factors that affect foundation drain flow. It was considered impractical to vary these conditions at private residences. Therefore, a test facility was constructed in Strathcona County in the fall of 1990. The facility's foundation drains, sump pump installations and site instrumentation were designed to carry out lot drainage testing. A series of four projects, investigating the impact of various lot characteristics on foundation drain flow was devised. This report describes the second project in the series.

The testing procedure used to assess the effects of the various lot drainage characteristics was:

- Apply a design rainstorm to the test facility
- Measure the foundation drain response to the rainstorm
- Measure the groundwater table response

The tests were repeated for combinations of the lot drainage characteristics listed above. Data for each test were recorded and the results analyzed and compared for the various characteristics.

The test program produced a wide range of responses in foundation drain flows. At the extremes, a well graded lot with proper drainage practice produced 0.47 L/s of foundation drain flow, while in comparison, the foundation drain response for a lot with poor drainage practices was 1.00 L/s for the same storm event.

The impacts of three significant lot characteristics as determined by this research are:

- Permeability of the material within the backfill zone - flows for sand backfill were approximately 10 times those for compacted clay backfill
- Grading of the backfill zone - drainage towards the foundation resulted in flows two times as high as for tests with drainage away from the foundation.
- Ground cover - the average peak inflow for the bare ground cover condition was one and one-half times greater than for the sod cover condition

These results are not multiplicative and were obtained when the parameter under consideration was varied while the others were held constant. That is, a lot with sand backfill, drainage towards the foundation and bare ground cover will not necessarily have flows 30 times those of a lot with clay backfill, drainage away from the foundation and sod ground cover.

The following recommendations for lot drainage characteristics reflect the findings of the project:

- Sandy soil is not recommended as a backfill material.
- Clay capping or a similar impermeable barrier within the backfill zone should be considered for situations where sandy soil must be used.
- The size of the backfill or construction zone around the foundation should be minimized.
- The grading zone around the house should be sloped a minimum of 5 percent away from the foundation.

An additional recommendation relates roof leader discharge practices to grading and soil type in the backfill zone. The effects of the recommendations listed above could be enhanced if roof leader flows are managed such that they discharge onto a suitable surface and to a point outside the backfill zone. Inflow rates for tests where the roof leaders discharged within the backfill zone, i.e. at the wall and at 1.5 m from the wall, were significantly higher than for the tests where discharge to storm sewers was simulated. These results indicate that roof leader discharges onto permeable backfill soils, such as sand, must be controlled. This can be accomplished by providing a suitable, less permeable discharge surface or by ensuring that the discharge point is outside the permeable backfill zone.

GLOSSARY OF TERMS

SOURCE: 1) Handbook of Steel Drainage and Highway Construction Products (Canadian Edition) American Iron and Steel Institute
2) Manufacturer's Literature

Backfill:	Earth or other material used to replace material removed during construction.
Backfill Compaction:	Percent compaction (density) for backfill (required or expected).
Block Rainstorm:	A synthetic design storm with uniform intensity that is the average intensity of the Chicago method.
Compaction:	The densification of a soil by means of mechanical manipulation.
Construction Zone:	The area adjacent to the house foundation that has been excavated for construction and backfilled once construction of the foundation was complete.
Data Logger:	A stand alone electronic storage device that records information on an assigned time interval.
Design Frequency:	The recurrence interval for hydrologic events used for design purposes. As an example a design frequency of 50 years means a storm of a magnitude that would be expected to recur on the average of once in every 50 years.
Design Storm:	A precipitation event that, statistically, has a specified probability of occurring in any given year (expressed either in years or as a percentage).
Discharge:	The actual volume of water flowing from a drainage structure per unit of time.
Download:	A complete memory transfer of all the data loggers' memory to a disk file (computer) for diagnostic purposes.
Drainage:	Interception and removal of ground water or surface water by artificial or natural means.
Engineered Soil:	A selected soil of known properties placed in a prescribed manner.
Foundation:	That portion of a structure (usually below the surface of the ground) which distributes the pressure to the soil. Footing has similar meaning.

Foundation Drain:	A perforated pipe which collects ground water from the foundation or footings for the purpose of draining unwanted waters away from such structures.
Grade:	Refers to slope, or ratio of fall of the grade line to its length.
Grading Zone:	The ground surface adjacent to the house foundation upon which surface runoff travels, preferably graded away from the house and extended beyond the construction zone.
Ground Water Table (Level):	Upper surface of the zone of saturation in permeable soil.
Head:	The height of water (energy) above any plane or point of reference.
Hydrograph:	A graph of runoff rate, inflow rate, or discharge rate versus time.
Hyetograph:	A graph showing average rainfall, rainfall intensities, or rainfall volume over specified areas, with respect to time.
Icing:	The gradual accumulation of ice resulting from freezing water over a period of weeks or months.
Impervious:	Impenetrable. Completely resisting entrance of liquids.
Infiltration:	The passage of water into the soil. The term is also used to refer to groundwater entering a sewer system through joints, manholes, etc., infiltration is not usually desirable in sanitary sewer systems, but may be desirable in urban storm drain systems to control the ground water table, and protect roadway pavements.
Inflow:	The water discharged into a sewer system from all possible sources but not infiltration.
Permeability:	A property of soils which permits free passage of any fluid. Permeability depends on grain size, void ratio, shape and arrangement of pores.
Return Period:	The average period in years between occurrences of a discharge equalling or exceeding a given value.

Roof Leader:	A drain or pipe that conducts storm water from the roof of a structure downward and into a sewer for removal from the property, or onto or into the ground for seepage disposal.
Surcharge:	The flow condition occurring in closed conduits when the hydraulic grade line is above the crown of the sewer.
Trapezoidal Rainstorm:	A simulated rainstorm for which the intensity is varied over the duration of the simulation to represent the intensity that occurs during the natural event. The plot of intensity versus duration of the event being simulated resembles the shape of a trapezoid.

1.0 INTRODUCTION

1.1 Objectives

Foundation drain systems around residential basements contribute significant flow into the sanitary or combined sewers to which they are connected. This flow can, and frequently does, result in:

- Sewer overloading, surcharging and basement flooding
- Increase in the frequency and duration of combined sewer overflows
- Extra capital and operating costs for collection and treatment facilities

The objectives of this project were to determine to what extent different construction and lot drainage characteristics affect foundation drain flow and to recommend general improvements to design and construction practices to reduce these flows for lots where sand is used as a backfill material. In support of these objectives, the effects of various lot characteristics on foundation drain flow were measured and analyzed.

Several factors including lot grading, backfill practice, ground cover, and roof leader locations affect the magnitude of foundation drain flow. Due to the inability to vary these factors at private homes, the Strathcona Research Facility was built with funding from Alberta Municipal Affairs, the City of Edmonton, Strathcona County and the New Home Warranty Program of Alberta. The facility, described in detail in the recently completed *Lot Drainage Characteristics Study - Clay Till Soils*, was designed to accommodate lot drainage research.

1.2 Project Scope

This project was the second in a series of four projects which together will comprise the overall Lot Drainage Characteristics Study. The projects will determine the extent to which different lot characteristics affect foundation drain flows in various backfill soils. Various aspects of the projects are illustrated by Figure 1. The findings will be used to determine design flow rates and identify possible improvements in construction methods and design standards to reduce foundation drain flows. The research findings may form the basis for new requirements in the Building Code. The research may also lead to recommendations that could reduce the costs of sewage collection systems and wastewater treatment facilities, and reduce the risk of basement flooding caused by sewer backup. A brief description of the original intent of the four projects (Figure 1) follows.

> Project 1 - Clay Till Soils The focus of this project was to establish benchmark correlations for certain parameters and to test foundation drain response for clay till soils.
>
> Project 2 - Lot Drainage Characteristics for Sandy Soils Incorporating the benchmark information from Project 1, testing was carried out on a sandy soil backfill, repeating combinations of lot characteristics similar to those in the clay till project. Accordingly, the soil type - permeability - became an additional lot characteristic variable. For sandy soils, uncompacted backfill was not tested since after initial water flushing the backfill was considered consolidated. Approximately twenty sets of data were gathered.

Lot Drainage Characteristics Study

Parameter	Project 1 Clay Till	Project 2 Sandy Soil	Project 3 Silty Soil	Project 4 Natural Storm Events
Storm Event	4 hr/5 yr 4 hr/50 yr 24 hr/5 yr 24 hr/25 yr	4 hr/5 yr 24 hr/5 yr	4 hr/5 yr 24 hr/5 yr	Natural Rainfall
Lot Variable				
Lot Configuration	Single Split	Single	Single	Single
Ground Cover	Bare Sod Typical	Bare Sod	Bare Sod	
Compaction of Backfill Zone	Compacted Uncompacted Engineered	Compacted	Compacted Uncompacted	
Grading of Backfill Zone	Good Poor Flat	Good Poor Flat	Good Poor Flat	
Roof Leader Discharge Location	1.5m Extension No Extension Storm Connection	1.5m Extension No Extension Storm Connection	1.5m Extension No Extension Storm Connection	
Measured Data Sets	70	24	30	

E:\25403\INITSCHD.DRW

Figure 1 Lot Drainage Characteristics Study Initial Schedule

Project 3 - Lot Drainage Characteristics for Silty Soils Testing similar to Projects 1 and 2 will be carried out on a silty soil backfill, again varying the soil type and testing the same lot characteristics, including the compacted and uncompacted conditions. Approximately thirty sets of data are planned.

Project 4 - Evaluation of Natural Storm Events Throughout the study, foundation drain response to natural storms will be monitored to provide additional data to complement the simulated storm tests. The data will represent approximately a 3-year record of foundation drain responses to natural storm events and possibly winter (rain) storm and snowmelt events. The objective of Project 4 is to analyze and correlate the natural event information to the simulated storm findings in the previous studies and combine all study findings into a comprehensive report/design manual.

1.3 Description of Research Method

The research method used for the project was that of an experimental study, where the characteristics such as compaction, grading and roof leader practices were independent variables and the foundation drain response was the dependent variable. Projects 2 and 3 varied soil type, or permeability, of the backfill zone. The test facility was designed to allow one independent variable to be changed while keeping the other factors constant and measuring the resulting foundation drain response.

The scope of work for this project included:

- Preparation of a work plan that provided flexibility and coordination for concurrent foundation wall research being carried out by the University of Alberta

- Preparation of the research facility for the testing of lot drainage characteristics
- Field testing and data collection for the simulated rainfall events
- Data collection for natural storm events
- Analysis and evaluation of the testing program results and formulation of recommendations

1.4 Organization of the Document

This report is divided into three ensuing sections:

1. Section 2.0 describes the testing procedures used for the work of this project.
2. Section 3.0 summarizes and provides an analysis of the test results for the various lot conditions.
3. Section 4.0 presents the conclusions and recommendations.

Figures and photographs are presented immediately after the text page in which they are referenced. The terminology used in the titles for some figures is based on the condition of the backfill zone. For example, "compacted good" refers to the site condition of compacted backfill with good grading around the foundation.

Appendix A contains sample field data sheets to illustrate aspects of the data collection process.

2.0 SITE DESCRIPTION AND TEST APPROACH

2.1 Test Site Description

The research facility is on the northeast corner of the Strathcona County Reservoir Site, 17th Street and 92nd Avenue, Strathcona County. The site is relatively level with a natural slope of approximately 4.3 percent to the north. It is bounded by gravelled roads on both the south and west sides as shown on Photo 1 and 2. Details of the research facility are presented in Project 1, *Lot Drainage Characteristics Study - Clay Till Soils.*

Photo 1. Research Facility Site - The site is being graded to establish a 1.5 percent, back-to-front slope. A flat grade of 1.5 percent was used based on the findings of previous research that suggested the greater the slope of the lot, the lesser the effect of storms on foundation drain response. Also, a lot grade of 1.5 percent is representative of homes that experience foundation drain flows. The photo was taken from the back of the lot looking north.

Photo 2. Site Work Completed - The photograph shows the facility with the site work completed. The photograph was taken from south (back) to north (front).

The foundation drainage system at the site was specially designed for foundation drain research. The facility can be operated as a single site or separated into two zones representing two sites - front-lot and back-lot. To provide this capacity, an impermeable geomembrane (Photo 3), cutoff footings and two sumps with related foundation drain valving, shown in Figure 2, were constructed. Both sumps were monitored for the duration of this project.

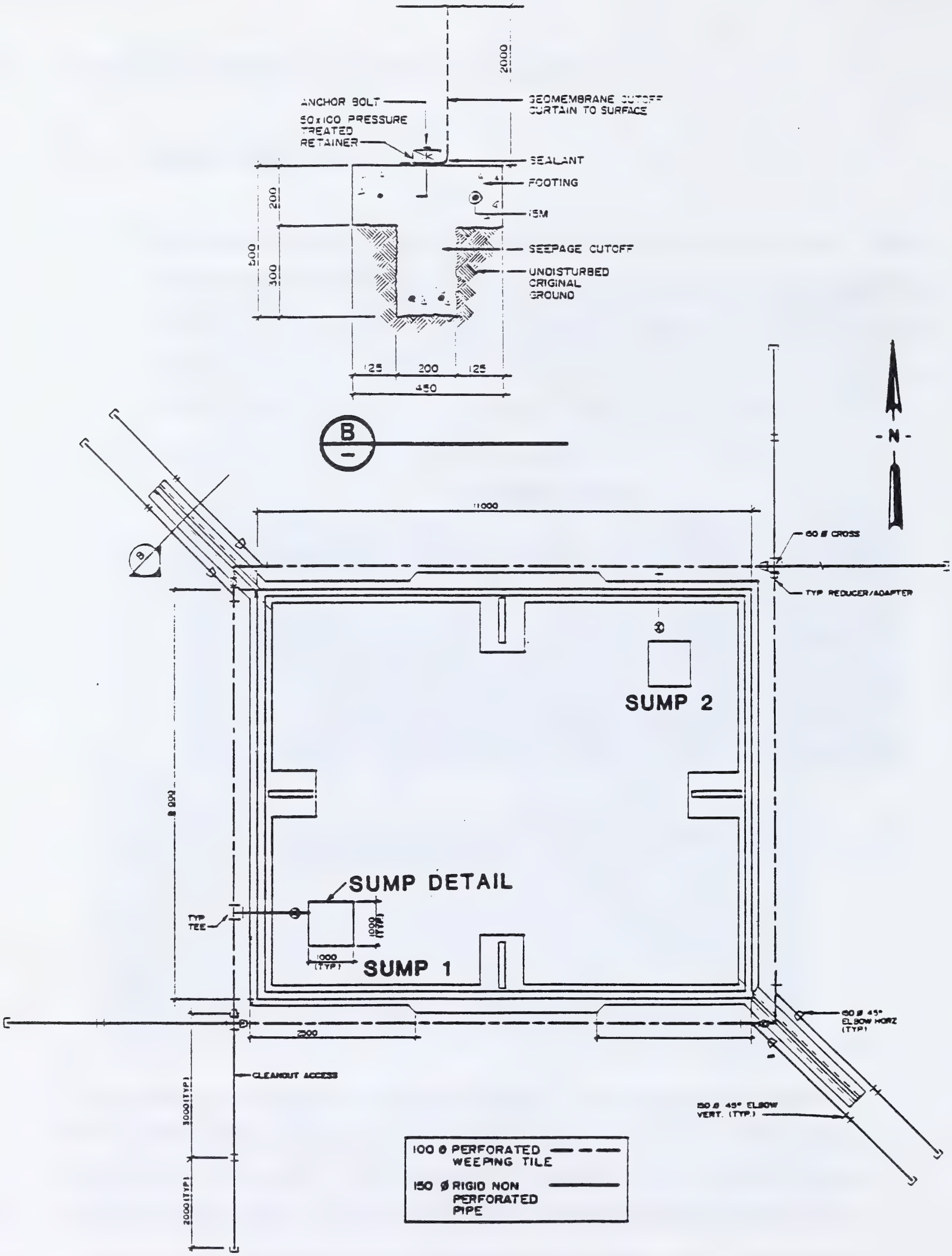

2000
ANCHOR BOLT
50 x 100 PRESSURE TREATED RETAINER
GEOMEMBRANE CUTOFF CURTAIN TO SURFACE
SEALANT
FOOTING
15M
SEEPAGE CUTOFF
UNDISTURBED ORIGINAL GROUND
200
500
300
125
200
125
450
B
N
11000
60 Ø CROSS
TYP REDUCER/ADAPTER
B
SUMP 2
8 000
SUMP DETAIL
TYP TEE
1000 (TYP)
1000 (TYP)
SUMP 1
2100
150 Ø 45° ELBOW HORZ (TYP)
CLEANOUT ACCESS
150 Ø 45° ELBOW VERT. (TYP.)
3000 (TYP)
2000 (TYP)
100 Ø PERFORATED WEEPING TILE
150 Ø RIGID NON PERFORATED PIPE

Figure 2 FOUNDATION DRAIN AND SUMP PLAN

Photo 3. Impermeable Geomembrane - An impermeable geomembrane attached to the cutoff footing and the foundation at diagonal corners of the facility separated (by closing appropriate valves) the subsurface flow of groundwater into back-lot and front-lot inflow.

2.2 Test Approach

2.2.1 Identification of Variables

The research method used for this project was experimental study. This method is used where there are several independent variables that may affect an outcome - in this study, the foundation drain response. The effect of each variable is determined by holding all variables constant except the one of current interest. The independent variables in this project are described below (refer also to Figure 1 in Section 1.2):

1. Ground cover conditions around the foundation walls, namely sod and bare earth.
2. Lot grading conditions adjacent to the foundation wall:
    - Poor (-2 to -5 percent)
    - Flat (-2 to +2 percent)
    - Good (>5 percent) slopes
3. Roof drain discharge locations:
    - At the basement wall
    - At 1.5 meters from the wall
    - Connected directly to the storm sewers
4. Storm types:
    - Short duration, high intensity - 4-hour duration, 5-year return period
    - Long duration, low intensity - 24-hour duration, 5-year return period

By varying one of the above independent variables per test, its effect on foundation drain response (the dependent variable) was determined.

On the lot drainage tests for other types of soil, backfill compaction was one of the variables investigated. However, for this project, sandy soils are considered compacted after a rain storm and compaction was therefore not investigated.

2.2.2 Field Testing

Analysis of the benchmark testing carried out in Project 1 - Clay Till Soils, suggested that the 4-hour 5-year rainfall event was most suited to this project. As a result, it was adopted as the standard for testing. A single 24-hour 5-year event was also included in the test program for continuity and confirmation purposes. The two defined rainfall events were simulated in the project for various combinations of site characteristics and the foundation drain flow was recorded prior to, during and after each simulation. Design hyetographs for the two storm events selected for simulation were developed in Project 1 - Clay Till Soils. The flowrate calculations for the simulated storms are presented in Figure 3 and the resulting hyetographs for the simulated storm events are shown by Figures 4 and 5.

The testing schedule was based on the results of benchmark testing carried out in Project 1 - Clay Till Soils. The schedule for this project was revised and is depicted in flowchart form by Figure 6.

Prior to the start of each test, the water levels in the 24 piezometers installed at various locations on the site were read and the base flowrate of the foundation drain system was determined. The site was configured for the given test.

The following tasks describe the test procedure:

- Select the flowrate of water to be distributed over the front yard and back yard through the sprinklers and soaker hoses from the downspouts.
- Ensure that the on/off sensors connected to the sump pumps and all water level recorders are functioning properly.
- Lay out soaker hoses to ensure even coverage of the lot and run hoses to the downspout discharge points.
- Start flow from the fire hydrant and open valves on the manifolds until the flow through the meters reaches the values calculated in Figure 3.

DESIGN STORM HYETOGRAPHS

4 - HOUR

5 - YEAR STORM - FRONT LOT

START TIME (min)	ELAPSE TIME (min)	INTENSITY mm/hr	DEPTH OF RAINFALL (mm) CALCULATED	ACTUAL	TOT FLOW (USGPM)	ROOF FLOW (USGPM)	ACCUM VOLUME
00:00	60	6.046	4.101	6.046	5.5	1.3	1.25
01:00	30	38.474	20.192	19.237	35.0	8.4	5.22
01:30	30	6.046	6.788	3.023	5.5	1.3	5.85
02:00	120	5.496	8.133	10.993	5.0	1.2	8.12
VOLUME(m^3)			8.10				
DIFFERENCE				0.085			

5 - YEAR STORM - BACK LOT

START TIME (min)	ELAPSE TIME (min)	INTENSITY mm/hr	DEPTH OF RAINFALL (mm) CALCULATED	ACTUAL	TOT FLOW (USGPM)	ROOF FLOW (USGPM)	ACCUM VOLUME
00:00	60	4.473	4.101	4.473	7.0	1.0	1.59
01:00	30	38.979	20.192	19.489	61.0	8.5	8.52
01:30	30	12.780	6.788	6.390	20.0	2.8	10.79
02:00	120	4.473	8.133	8.946	7.0	1.0	13.97
VOLUME(m^3)			13.94				
DIFFERENCE				0.084			

24 - HOUR DESIGN STORM

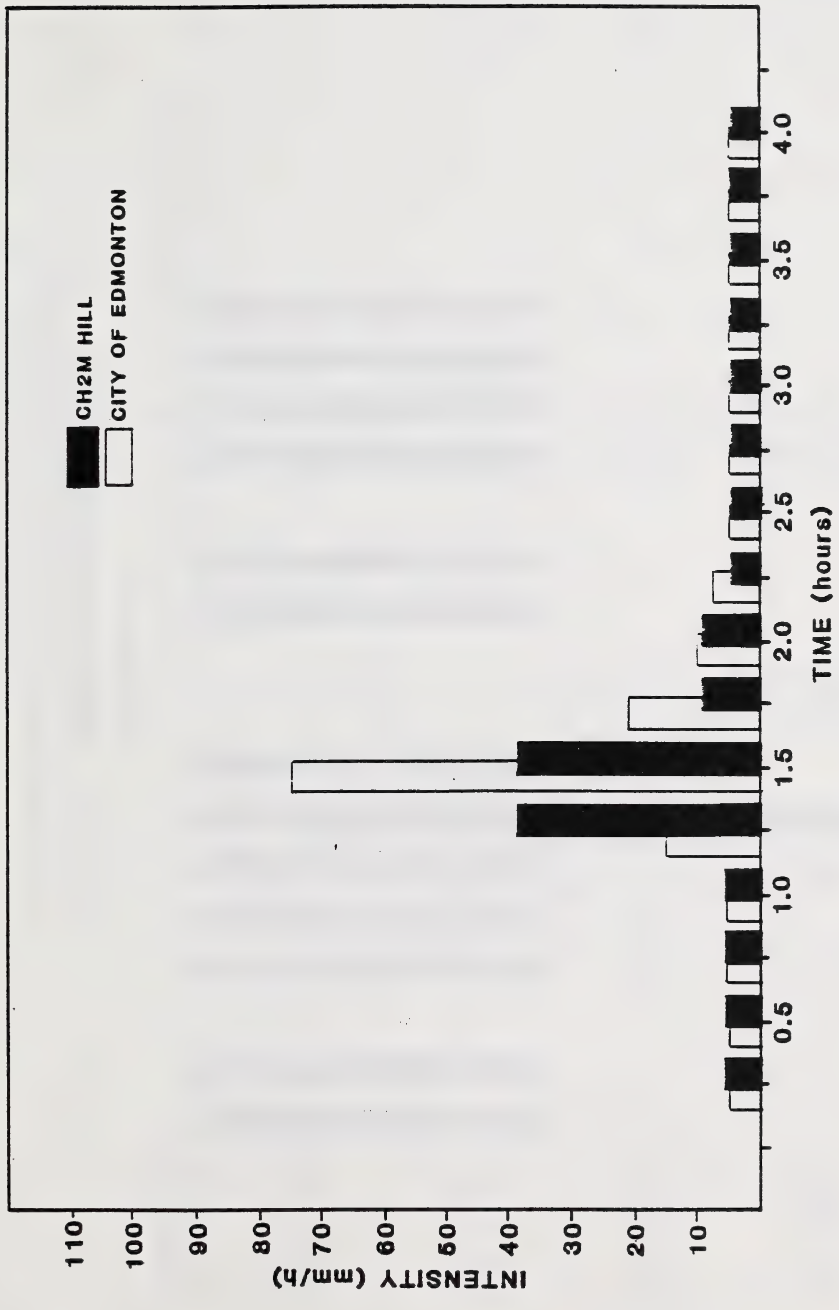
5 - YEAR STORM - FRONT LOT

START TIME (min)	ELAPSE TIME (hr)	INTENSITY mm/hr	DEPTH OF RAINFALL (mm) CALCULATED	ACTUAL	TOT FLOW (USGPM)	ROOF FLOW (USGPM)	ACCUM VOLUME
03:00	1.5	5.496	14.357	8.244	5.0	1.2	1.70
06:00	1	5.496		5.496	5.0	1.2	2.84
08:00	1	5.496	5.447	5.496	5.0	1.2	3.97
09:00	1	12.642	12.446	12.642	11.5	2.8	6.59
10:00	1	6.596	6.637	6.596	6.0	1.4	7.95
13:00	2	5.496	23.725	10.993	5.0	1.2	10.22
16:00	2.5	5.496		13.741	5.0	1.2	13.06
VOLUME(m^3)			12.93				
DIFFERENCE				-0.596			

5 - YEAR STORM - BACK LOT

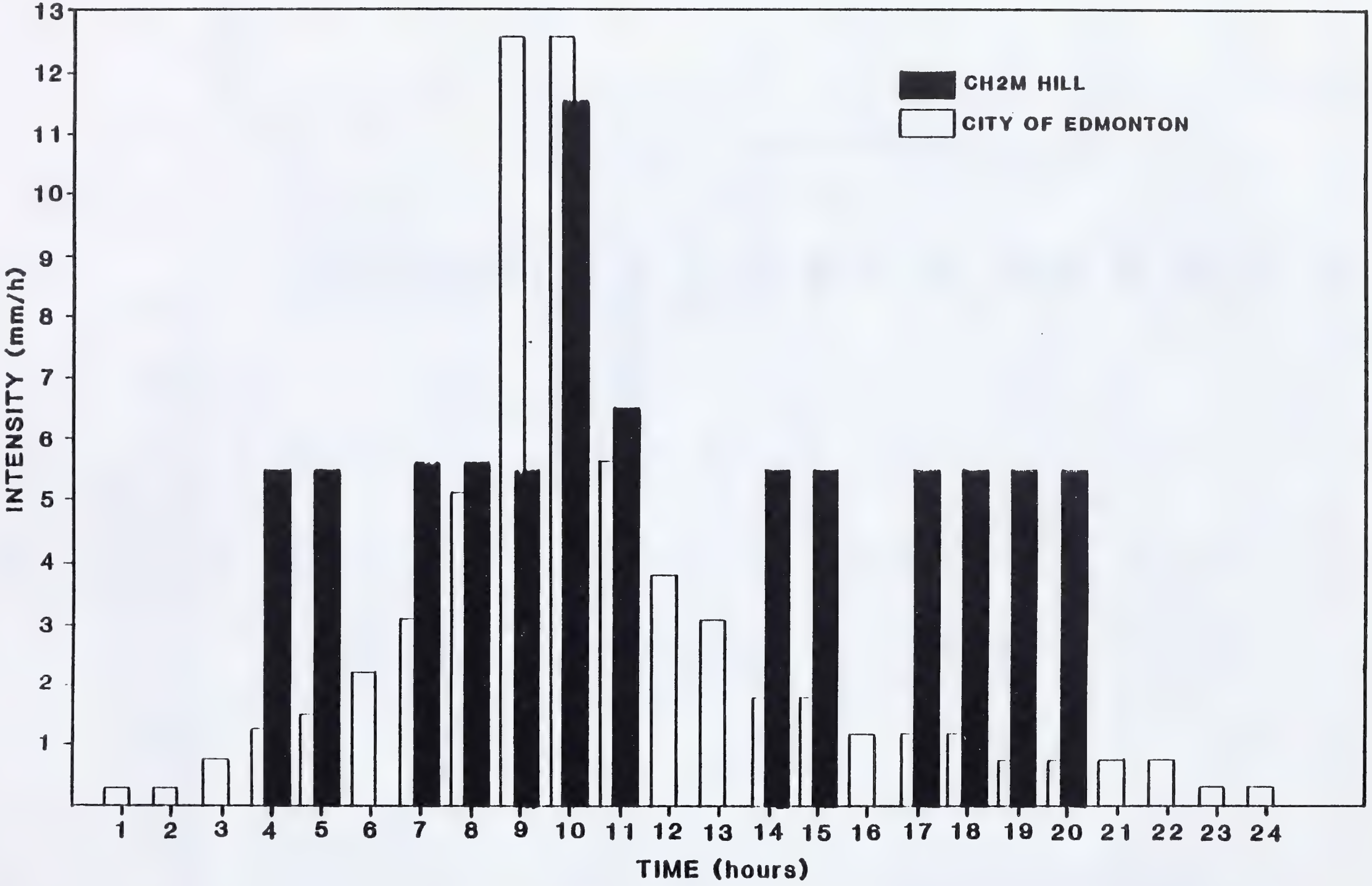
START TIME (min)	ELAPSE TIME (hr)	INTENSITY mm/hr	DEPTH OF RAINFALL (mm) CALCULATED	ACTUAL	TOT FLOW (USGPM)	ROOF FLOW (USGPM)	ACCUM VOLUME
03:00	1.5	5.431	14.357	8.147	8.5	1.2	2.90
06:00	1	5.751		5.751	9.0	1.3	4.94
08:00	1	5.431	5.447	5.431	8.5	1.2	6.87
09:00	1	12.460	12.446	12.460	19.5	2.7	11.30
10:00	1	6.390	6.637	6.390	10.0	1.4	13.57
13:00	2	5.431	23.725	10.863	8.5	1.2	17.43
16:00	2.5	5.431		13.579	8.5	1.2	22.25
VOLUME(m^3)			22.25				
DIFFERENCE				0.009			

Figure 3 FLOWRATE CALCULATIONS FOR STORM EVENTS



4-HOUR 5-YEAR DESIGN STORM

Figure 4



24-HOUR 5-YEAR DESIGN STORM

Figure 5

LOT DRAINAGE CHARACTERISTICS STUDY
SANDY SOIL BACKFILL

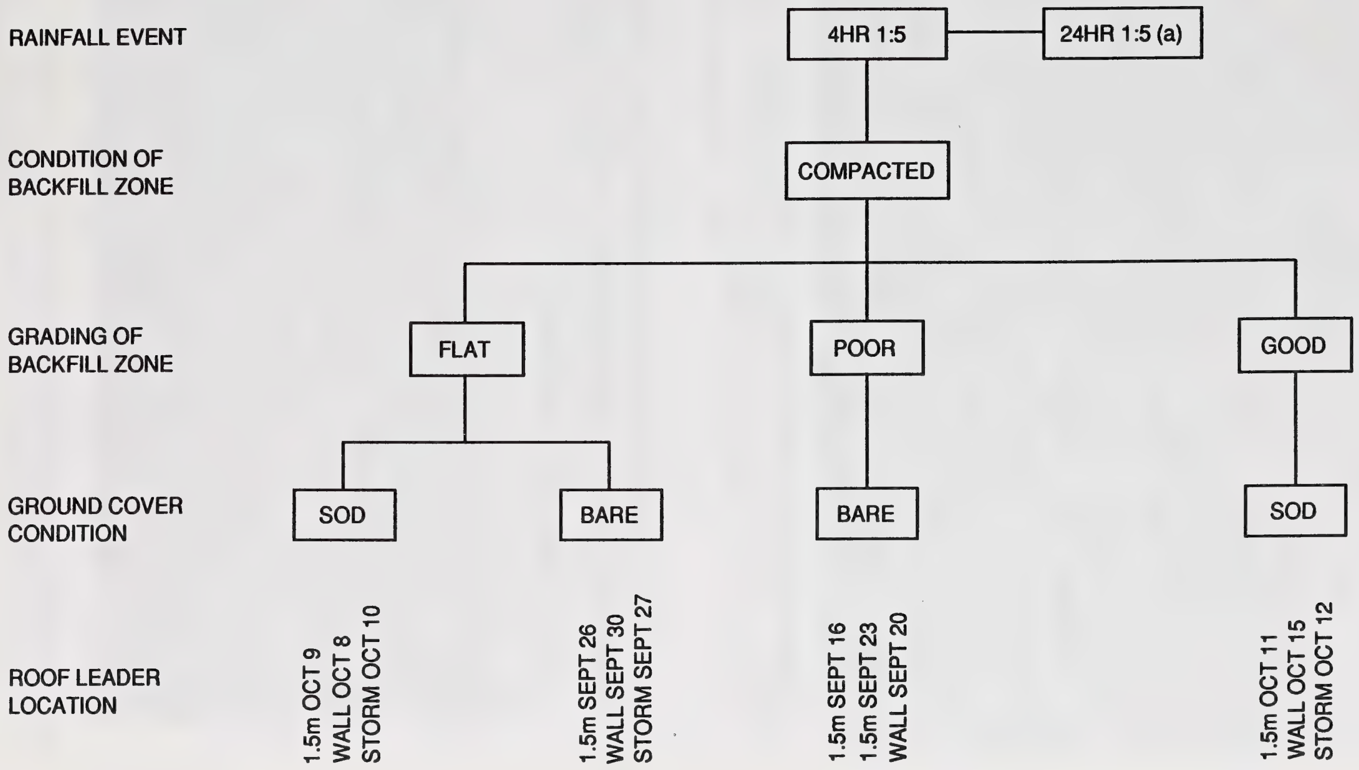


Figure 6 DATES OF FIELD TESTING

- Adjust the valves for the specified flowrate for the test design hyetograph.
- Stop the flow of water from the fire hydrant after the required volume of water has been applied.

During each simulation the piezometer, pump on/off and sump water level recorder readings were stored on the data loggers. Piezometer readings provided groundwater response data; pump on/off sensors provided pump running time data; and sump water level recorders provided data on the volume of the water discharged by the foundation drain system. The pump on/off sensors and the water level recorders were left in place and monitored continuously throughout the testing program, so that foundation drain flows could be recorded during naturally occurring rainfall events. Recorded data were downloaded from the data loggers on a daily basis.

Sump water was discharged to the surface, into a drainage ditch immediately north of the research facility. Discharge water did not re-enter the foundation drain system.

The equipment recorded relevant data 24 hours per day. Throughout the testing program the equipment performed satisfactorily, and the data record was complete. Photos 4 through 9 illustrate various test assemblies.

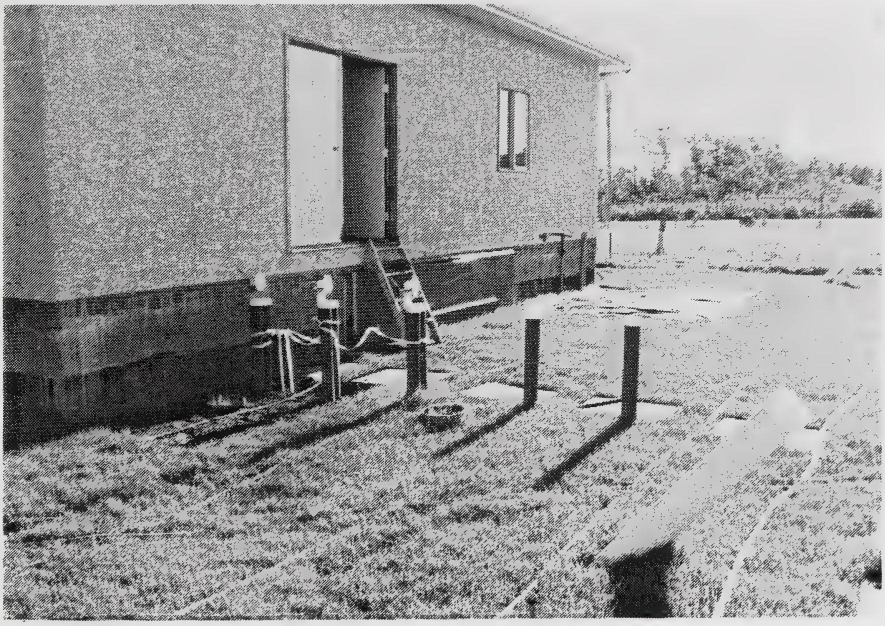


Photo 4. Piezometers - The five back-yard piezometers are pictured. The three piezometers in the backfill zone are equipped with a pulley-float-counterweight assembly that make up water level recorders.

Photo 5. Raingauge - Raingauge Station 90 was established onsite May 8, 1991. The station had a Rimco raingauge complete with data logger. The portable computer for downloading is also in the photo.

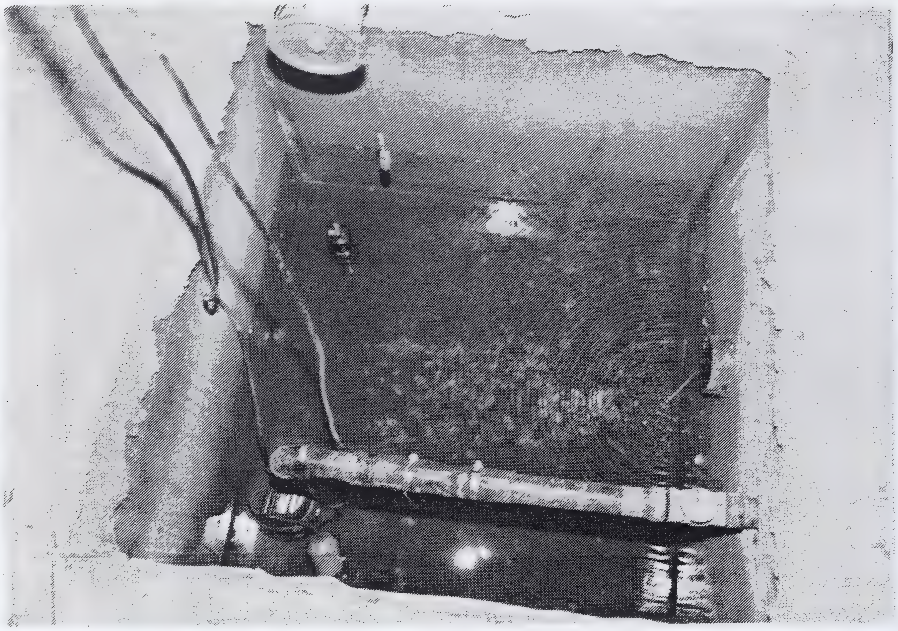


Photo 6. Water Level Recorder - The water level recorders are a pulley-float-counterweight assembly. The pulley's fixed axle has a potentiometer that indirectly reads water level as the float moves up and down.

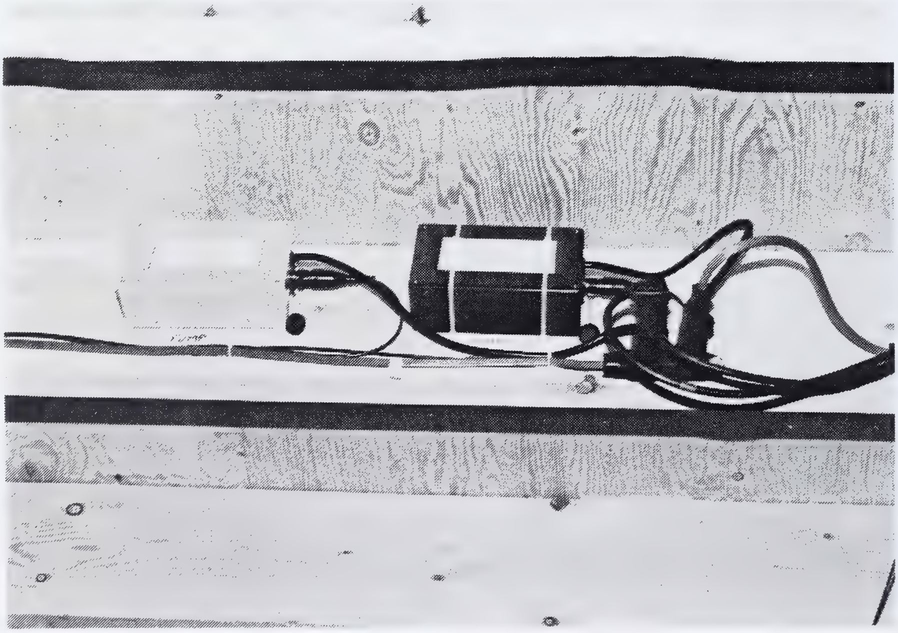


Photo 7. On/off Current Sensor - The on/off current sensors for the sump pumps record the time of pump starts and stops. Pump cycle time and foundation drain discharge volumes are also measured.

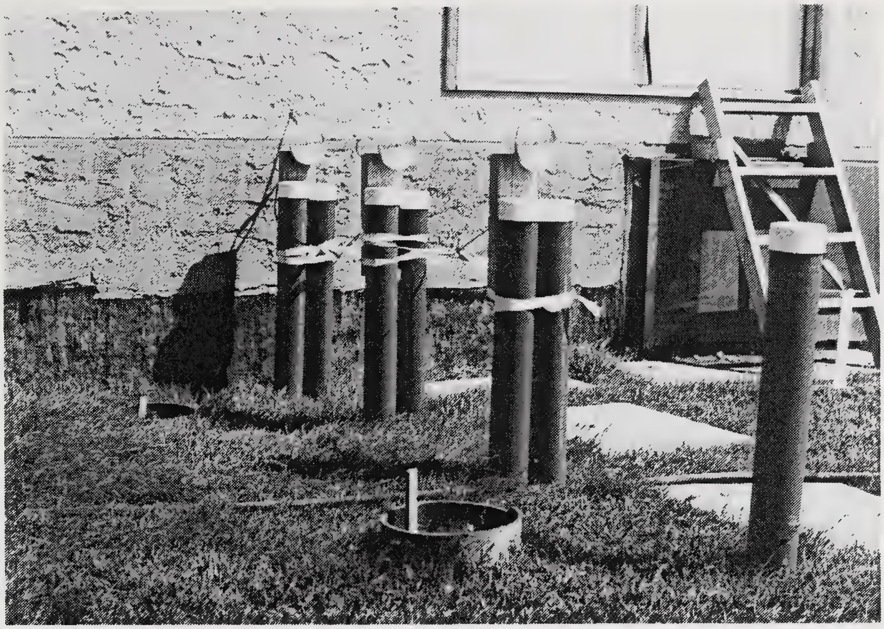


Photo 8. Infiltrometer - Two single ring, flooding type infiltrometers are marked by the survey stakes. PVC pipes were driven into the backfill zone and native soil to quantify infiltration rates.

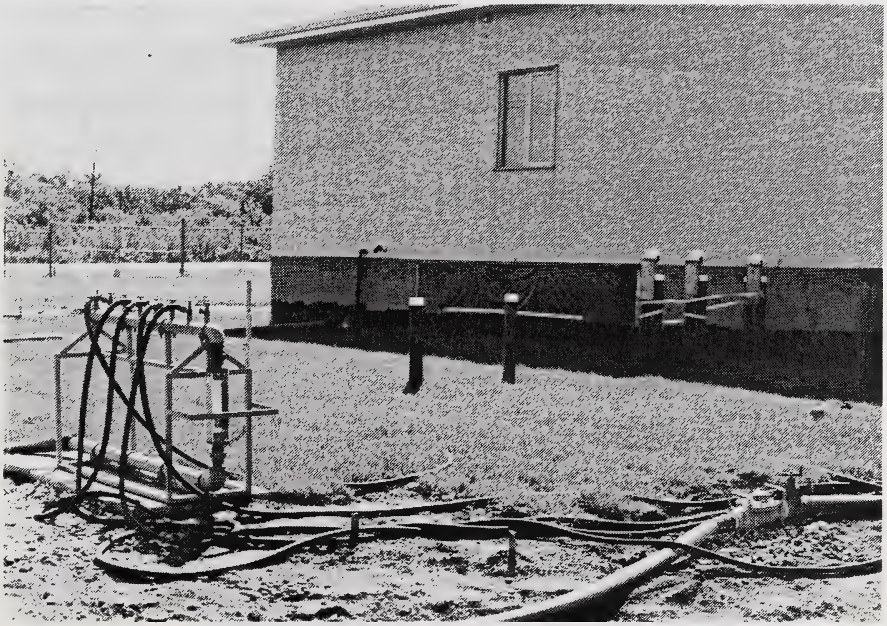


Photo 9. Rainfall Simulation Manifold - This photograph pictures one of four rainfall simulation manifolds complete with a variable area flowmeter. In the bottom right hand corner is the volume water meter on the fire hose.

3.0 TEST RESULTS AND ANALYSIS

This section of the report describes the testing program results and the analysis of the results and is presented in the following sequence:

- Section 3.1 describes how the test records were interpreted
- Section 3.2 through 3.5 presents the analysis of the test results in the following order of lot drainage characteristics:
    - Ground cover conditions
    - Grading of the backfill zone
    - Location of roof leaders
    - Groundwater response

3.1 Data Interpretation

The lot drainage characteristics study field testing for sandy soil was carried out from September 16 to October 15, 1991. Heavy snowfall and cold temperatures commencing on October 16, 1991 cancelled further 1991 testing. The test program data record is summarized in this section of the report. Tests were conducted on 12 days using both sump pumps. The front and back-lot inflow records yielded 24 sets of data. Summarized data are presented later in this section.

3.1.1 Interpretation of Summary Figures

Figure 7, Summary of Simulations, presents the overall test results and the test of September 23 is used throughout this section of the report as an example of how the data was processed and interpreted. Following are brief explanations of the column headings of Figure 7:

Test Date	Date of the simulation
Storm	Type of storm simulated
Start Time	Time test started

SUMMARY OF SIMULATIONS

TEST DATE	STORM	START TIME	VOLUME APPLIED (L)	INTENSITY APPLIED (mm/hr)	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN EXCLUDING NATURAL RAINFALL				TIME TO PEAK		GRADING	GROUND COVER	ROOF LEADER LOCATION
						FRONT	BACK	TOTAL (AVG.)	BASEFLOW(EXCL.) TOTAL	Tp (min)	Pp (min)			
16-Sept	4-hr/5-yr	11:30	22040	40.38	0.6298	76.35	40.57	54.89	53.89	96.49	21.49	POOR	BARE	1.5m
20-Sept	4-hr/5-yr	11:00	22040	40.38	0.9963	40.37	45.94	42.89	41.89	116.90	41.90	POOR	BARE	WALL
23-Sept	4-hr/5-yr	11:45	22040	40.38	1.0298	34.89	48.15	43.26	42.26	115.05	40.05	POOR	BARE	1.5m
26-Sept	4-hr/5-yr	11:45	22040	40.38	0.7705	28.97	44.12	38.55	37.55	145.11	70.11	FLAT	BARE	1.5m
27-Sept	4-hr/5-yr	10:00	22040	40.38	0.5372	21.69	35.77	30.59	29.59	126.18	51.18	FLAT	BARE	STORM
30-Sept	4-hr/5-yr	09:00	22040	40.38	0.6491	39.62	40.23	40.00	39.00	142.88	67.88	FLAT	BARE	WALL
8-Oct	4-hr/5-yr	09:30	22040	40.38	0.6847	33.61	35.66	34.91	33.91	100.20	25.20	FLAT	SOD	WALL
9-Oct	24-hr/5-yr	06:00	35180	12.45	0.4803	60.52	44.61	50.48	47.48			FLAT	SOD	1.5m
10-Oct	4-hr/5-yr	12:00	22040	40.38	0.4871	29.35	39.08	35.51	34.51	137.31	62.31	FLAT	SOD	STORM
11-Oct	4-hr/5-yr	12:20	22040	40.38	0.4741	37.69	41.67	40.21	39.21	181.85	106.85	GOOD	SOD	1.5m
12-Oct	4-hr/5-yr	14:10	22040	40.38	0.3040	16.87	26.95	23.25	22.25	225.69	150.69	GOOD	SOD	STORM
15-Oct	4-hr/5-yr	10:15	22040	40.38	0.4810	26.63	34.86	31.84	30.84	218.96	143.96	GOOD	SOD	WALL

Figure 7 SUMMARY OF SIMULATIONS

Volume Applied	Volume of water put on the site
Intensity Applied	Maximum intensity of storm hyetograph
Peak Recorded Inflow	Peak rate of inflow for simulation

The next six columns in Figure 7 are calculated values and are explained below.

% Entering Foundation Drain - Water level recorders were installed in both sumps to measure water levels at 4 min intervals. The area of the sump multiplied by the change in water level during the time interval is the volume of inflow during the interval. The rate of inflow is the volume divided by the time. The total volume of foundation drain inflow is the summation of the incremental volumes of water over the test period (the test period was a 12-hour duration commencing at the test start time). The percent entering the drain is the volume of inflow entering the sump divided by the volume of water applied to the site. The Front and Back columns are the ratios of the volume applied to inflow entering for the single lot, dual sump configuration.

The Total column is the ratio of the accumulation of front and back-lot inflows for the dual sumps.

The Total - Baseflow Excluded column is the percent entering ratio minus the baseflow. After the initial test simulations, the backfill soil was sufficiently wetted to yield a constant flow (baseflow) to the foundation drain. This baseflow was subtracted from the volume of inflow water for each simulation to yield the storm induced inflow.

Time to Peak - The timing of the storm induced response is an important value in drainage engineering and was recorded for each test. The time of maximum inflow was visually interpreted from the individual response hydrographs and measured from the start of the rainfall simulation (Tp) and from the time of maximum intensity of the storm hyetograph (Pp).

The remaining columns of the summary sheets are the site conditions for the simulation.

3.1.2 Interpretation of Inflow Hydrographs

The data from each simulation were analyzed and inflow (response) hydrographs were developed. The hydrographs were derived from the measured inflow data; therefore, they include baseflow components. Sample inflow hydrographs are shown by Figures 8 to 10.

The response hydrograph shows the rainfall-induced inflow to the foundation drain in relation to the time of the storm event. The hydrographs have two vertical scales. The main scale shows the rate of inflow in litres per second. The one in italics shows the precipitation intensity in millimetres per hour. The inflow rate is plotted as a line on the graph; precipitation is shown as a hatched area at the top, indicating the intensity and duration of the simulated event. The lot characteristics for the simulation are presented in the top right hand corner of the graph.

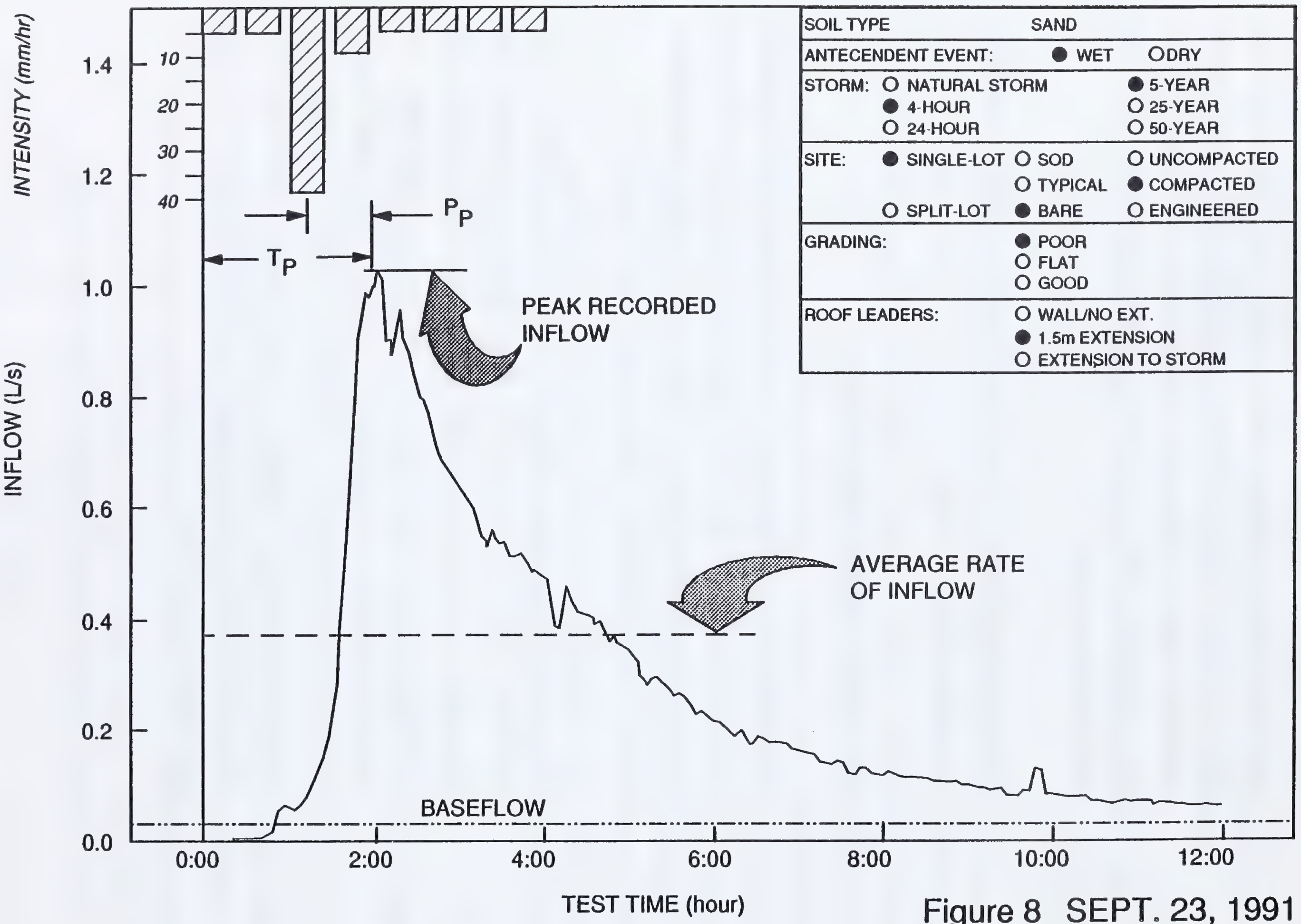


Figure 8 SEPT. 23, 1991
TOTAL-LOT

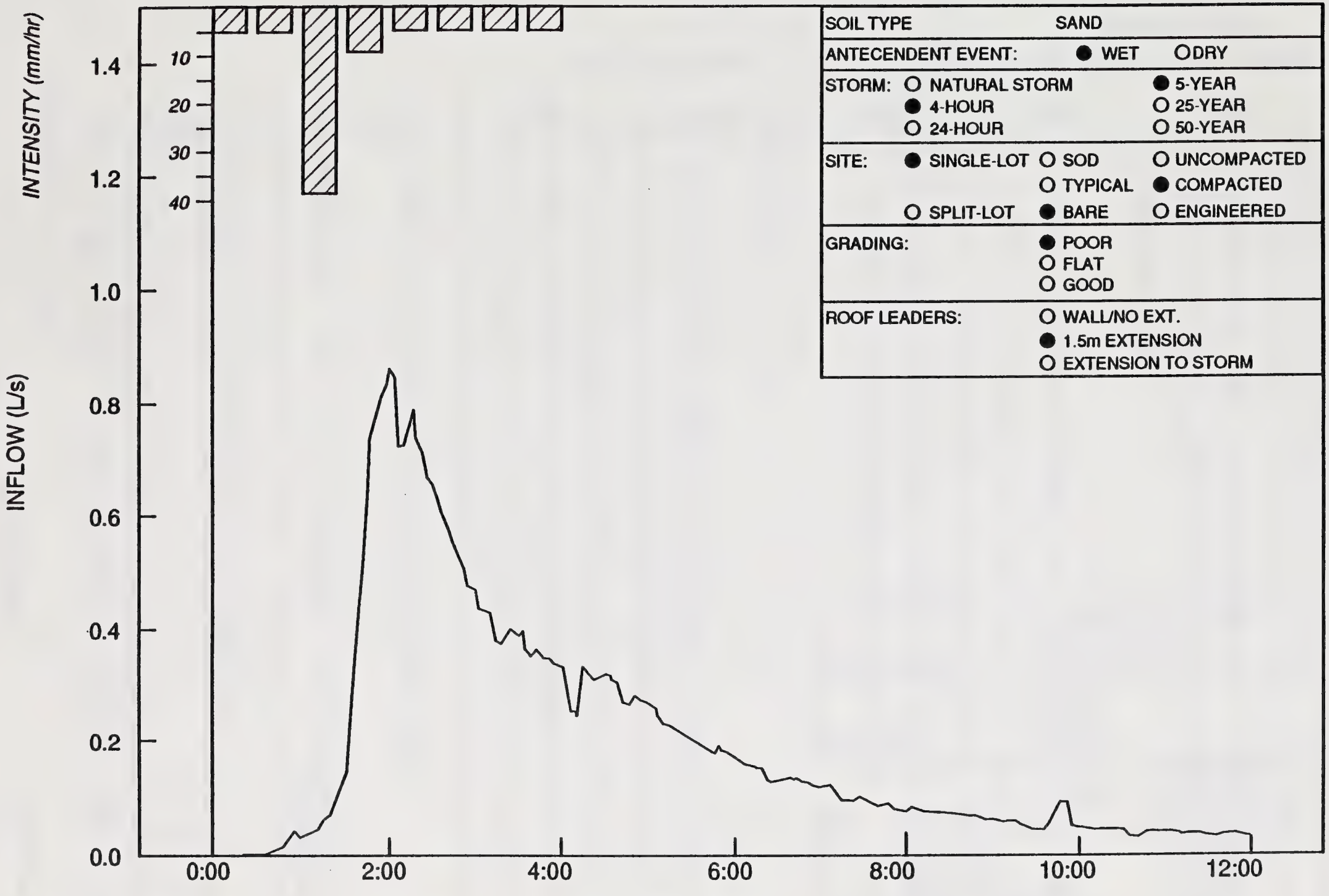


Figure 9 SEPT. 23, 1991
BACK-LOT

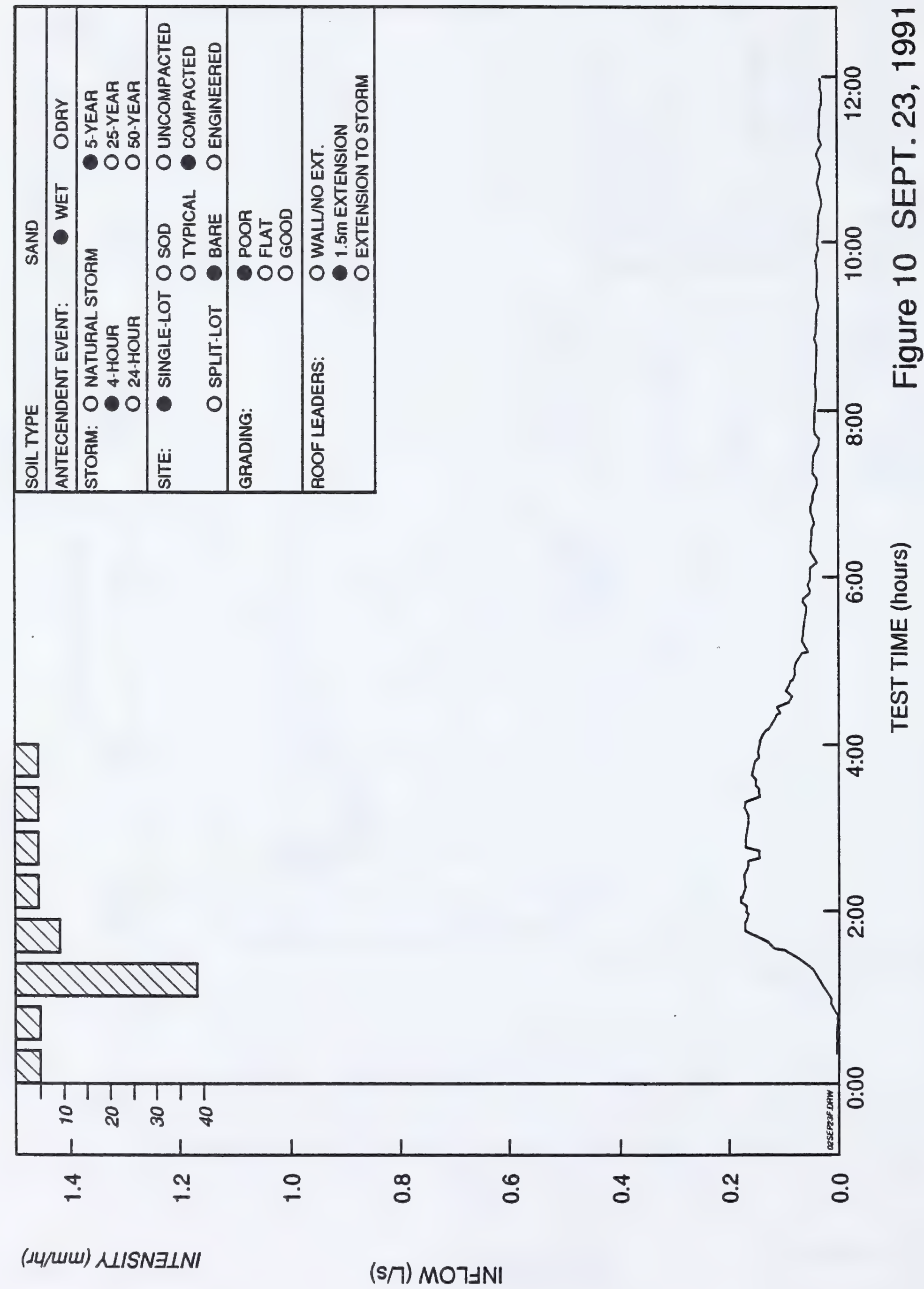


Figure 10 SEPT. 23, 1991 FRONT-LOT

The response hydrograph shows the inflow rate throughout the storm and the area under the curve is the volume of water conveyed through the foundation drain. As previously described, dividing the volume of inflow by the water applied yields the percent of water entering the foundation drain.

Figure 8 is labelled to identify some of the values listed on Figure 7. To illustrate, the values of peak inflow and Pp for September 23 from Figures 7 and 8 are 1.0298 L/s and 40.05 min respectively. The lot configuration (characteristics as described in Section 2.0) for the test is detailed in the top right-hand corner of each graph.

3.2 Ground Cover

The simulations from September 16 to September 30 tested for bare ground cover and sod ground cover was tested from October 8 to October 15. The responses from the simulations in which the roof leaders discharged off the site (to storm sewer) and the 24 hour/5 year simulation were not used in the calculation of average foundation drain responses for the two ground cover conditions. The sod did not establish (root) itself during the testing period, and therefore the lot simulated a recently landscaped yard.

The average peak inflow for the bare ground cover condition is 1.6 times greater than for the sod cover condition. The average peak responses were 0.815 L/s and 0.547 L/s for bare and sod, respectively.

The difference between the average percent entering was not as significant as the average peak inflow. The average percent entering was 43 for bare cover and 35 for sod cover.

These results suggest that sod cover does prevent some water from entering the foundation drain, however, its impact of slowing the response and reducing the peak inflow is more significant.

3.3 Grading of the Backfill Zone

Test simulations on September 16 to 23 were used for the poor grading condition. Tests from September 26 to October 10 provided data for the flat grading condition and the simulated events on October 11 and October 15 were used for good grading. The responses from the simulations in which the roof leaders discharged off the site (to storm sewer) and the 24 hour/5 year simulation were not used in the calculation of average foundation drain responses for the three grading conditions. Representative values for each grading condition are illustrated on Figure 11.

The average peak responses for poor and flat grading were 1.9 and 1.5 times greater than those recorded for good grading. They were 0.885 L/s for poor grading, 0.701 L/s for flat, and 0.478 L/s for good grading.

The average percentage entering the foundation drain for the poor grading condition was 46, while for flat and good grading the averages were 37 and 35 percent, respectively.

The average peak inflow responses and average percent entering the foundation drain were as expected - poor grading resulted in the greatest response, while good grading resulted in the lowest response.

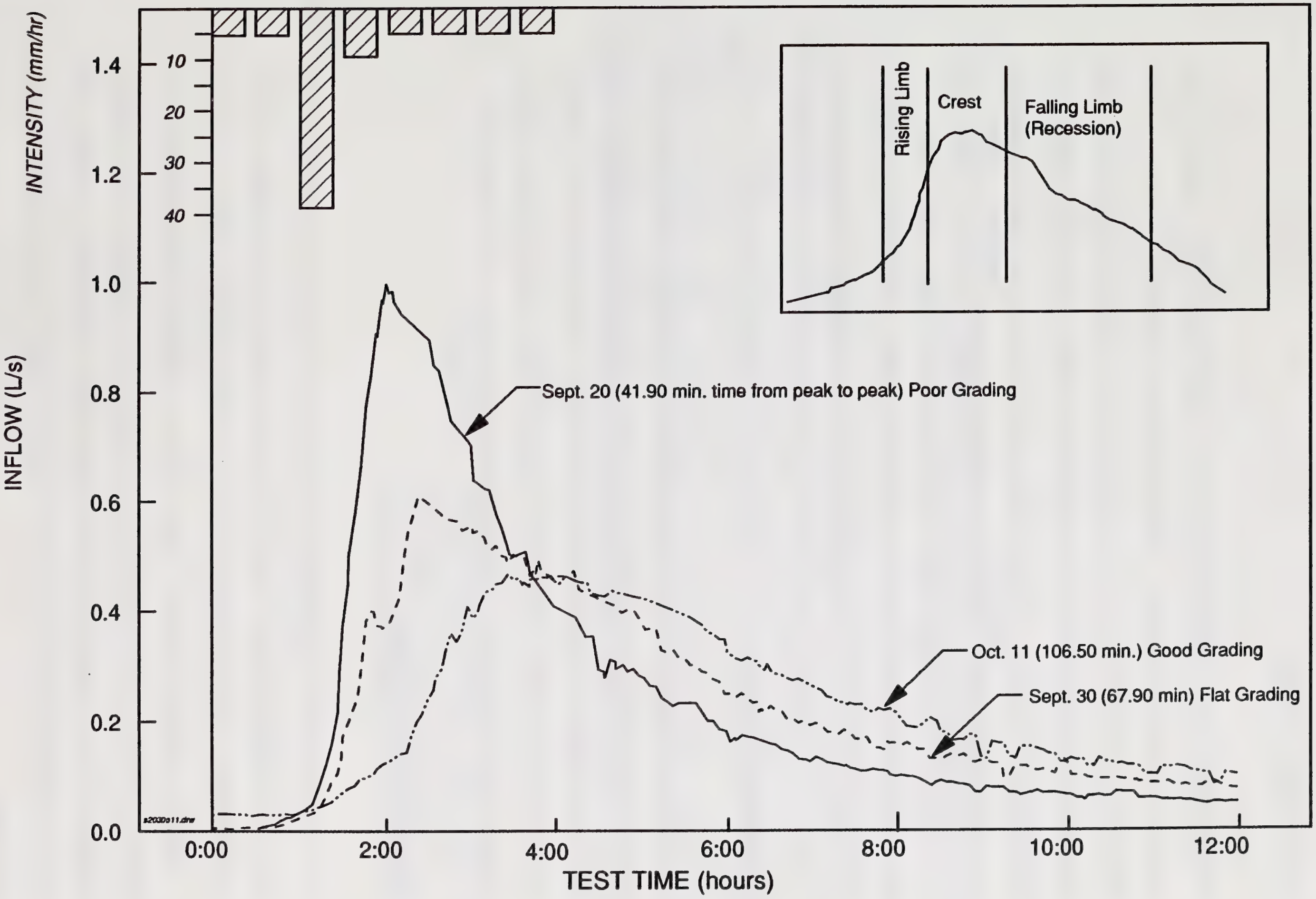


Figure 11 COMPARISON OF HYDROGRAPH SHAPES

3.4 Roof Leader Location

No foundation drain response pattern was established with respect to the location of the roof leader. The backfill zone extended 2 m from the foundation and with the 1.5 m extension on the roof leader the water still discharged onto the backfill zone, and therefore there was no reduction in the foundation drain response. The average peak inflow and percent entering for the tests which simulated roof leader discharging to storm were 0.443 L/s and 29 percent which is significantly less than the average for the other two locations, which were 0.714 L/s and 40 percent. The 24-hour/5-year simulation of October 9 was not included in this calculation of average flows.

3.5 Groundwater Response

The piezometers showed minor fluctuations in the water table during each simulation and during the testing period. These minimal fluctuations in the water table indicate that the backfill material was free draining. As a result approximately 40 percent of the water applied during sandy soil tests entered the drain tile as opposed to 4 percent entering the drain tile for clay soils.

3.6 Evaluation of Test Results

The final evaluation to quantify the impacts that various lot characteristics have on foundation drain flows will be carried out on completion of the overall study as outlined in Section 1.0. A preliminary evaluation of Project 2 - Sand is presented below. Figure 12 is a ranking of foundation drain responses that was derived from the testing. For consistency, this ranking includes only test results for 4-hour/5-year storm simulations and does not include results for those tests in which the roof leader was connected to the storm sewer.

TEST DATE	PEAK RECORDED INFLOW (L/s)	% ENTERING FOUNDATION DRAIN DESIGN STORM	LOT CONFIGURATION									
			COMPACTION		GRADING			GROUND COVER			ROOF LEADER	
			UNCOMP.	COMPACTED	POOR	FLAT	GOOD	BARE	SOD	TYP	WALL	1.5 m. EXT.
23-Sep-91	1.0298	42.26		X		X		X				X
20-Sep-91	0.9963	42.89		X	X			X			X	
26-Sep-91	0.7705	37.55		X		X		X				X
08-Oct-91	0.6847	33.91		X		X			X		X	
30-Sep-91	0.6491	39.00		X		X		X			X	
16-Sep-91	0.6298	53.89		X	X			X				X
15-Oct-91	0.4810	30.84		X			X		X		X	
11-Oct-91	0.4741	39.21		X			X		X			X

Figure 12 TEST RESULTS IN DESCENDING ORDER OF PEAK RECORDED FOUNDATION DRAIN FLOW

The previous studies conducted on compacted clay soil suggested drain responses in the order of 0.06 L/s, while for sand the responses ranged from 0.47 to 1.03 L/s. The sand responses were of the same order of magnitude of those for uncompacted clay. This suggests that the permeability of the sandy soil had the most significant impact on foundation drain response. The impact of the other site variables tested, including backfill zone grading, roof leader locations, and ground cover, are not as significant when compared to the permeability of the backfill.

The property of increased water conveyance of the sand is also demonstrated when comparing the 4-hour storm event to the 24-hour storm event, shown on Figure 13. The maximum rainfall intensity for the 4-hour and 24-hour events were 40 mm/hr and 12 mm/hr, respectively, while the peak inflows were similar. This result indicates that the permeability of the backfill material is a significant factor in contributing to foundation drain flows.

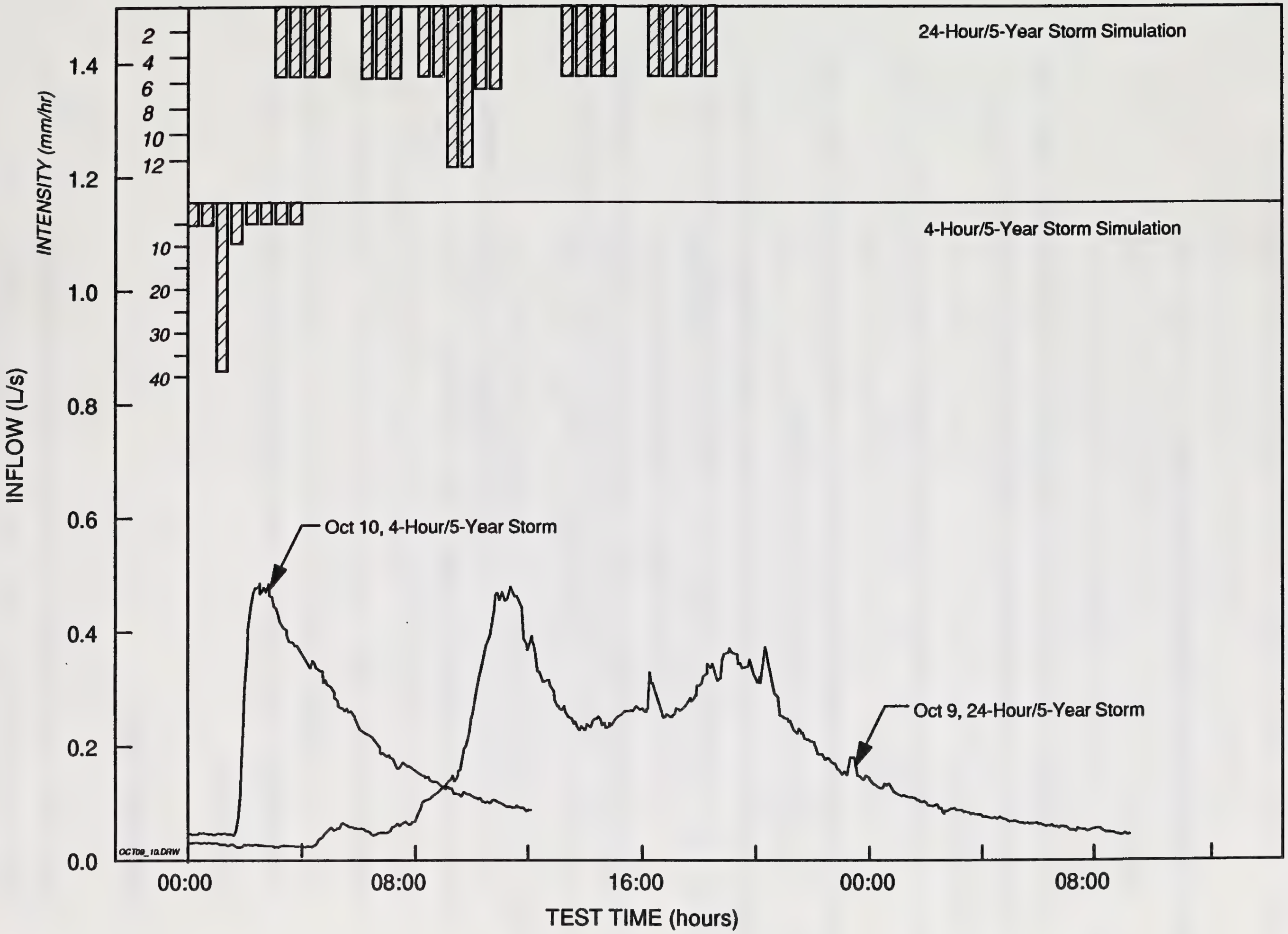


Figure 13 STORM EVENT COMPARISON

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Of the variables tested for sandy soil, ground cover and grading within the backfill zone, had reasonably significant impacts on foundation drain response. In particular:

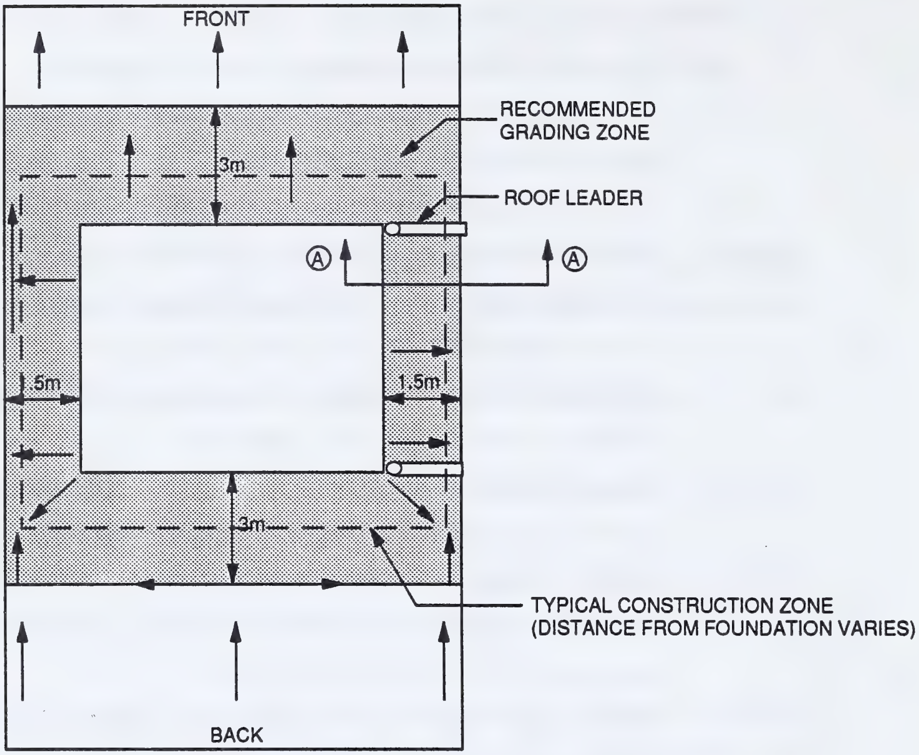
- Average peak inflow was 0.815 L/s for bare cover and 0.547 L/s for sod cover.
- Average peak inflow was 0.885 L/s for poor grading, 0.701 L/s for flat grading and 0.478 L/s for good grading.
- There was no significant difference in peak inflows for varied location of the roof leader discharge, except where discharge to storm sewer simulations resulted in lower foundation flows.
- The permeability of backfill material appears to influence foundation drain response more significantly than the other characteristics tested.

Surcharging of sanitary sewer systems and the resulting flooding of basements due to excessive foundation drain flows is possible. In Project 1 - Clay Till Soils, a review of studies related to foundation drain flows showed that the average maximum flows ranged from 0.16 to 0.19 L/s. All sandy soil test results were significantly greater than this and it is concluded that sand is not an acceptable backfill material when minimizing system inflow is a design consideration.

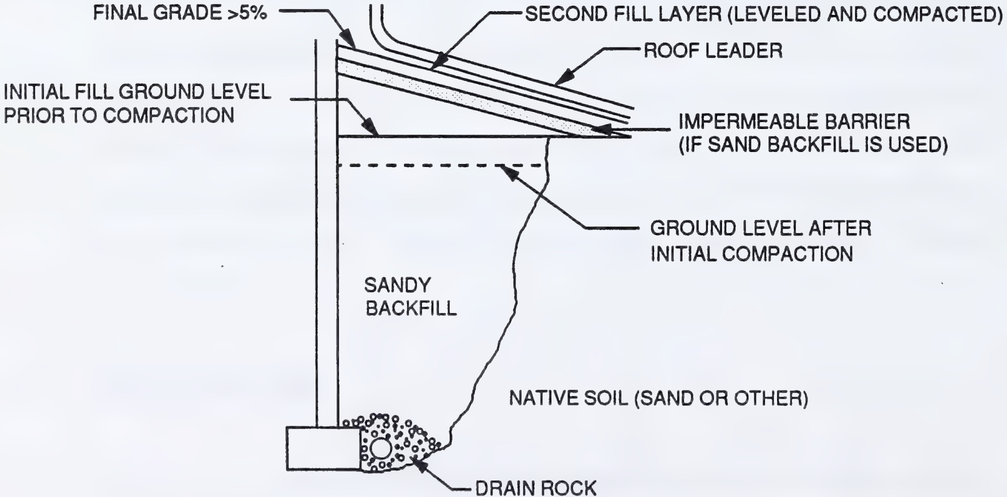
4.2 Recommendations

Sandy soils are not desirable for use as backfill material around foundation walls when minimizing system inflow is a design consideration and are not recommended as backfill material. In instances where the use of sand is unavoidable, the following recommendations are suggested:

1. The construction zone should be minimized in situations where sand must be used as a backfill material.
2. It is recommended that the grading of the area adjacent to the foundation walls (grading zone) be sloped a minimum of 5 percent away from the foundation. The grading zone would be defined as a 1.5 m width (minimum) at the side yards and 3.0 m in the back-and-front-yards. Where property lines permit, side-yard grading zones should be increased to 3.0 m. See Figure 14.
3. It is recommended where sandy soil must be used for backfill purposes, that an impermeable soil/barrier (clay cap, geomembrane or other suitable means) over the sandy soil within the backfill zone be considered (Figure 14). The impermeable barrier may reduce the amount of flow to an acceptable level.
4. Roof leaders should not discharge within a sand backfill zone. This can be accomplished by implementing other recommendations noted above, and/or by discharging roof leader flows farther from the house, beyond the backfill zone.



RECOMMENDED GRADING ZONE
SLOPE - MINIMUM 5%


FINAL GRADE >5%
SECOND FILL LAYER (LEVELED AND COMPACTED)
ROOF LEADER
INITIAL FILL GROUND LEVEL PRIOR TO COMPACTION
IMPERMEABLE BARRIER (IF SAND BACKFILL IS USED)
GROUND LEVEL AFTER INITIAL COMPACTION
SANDY BACKFILL
NATIVE SOIL (SAND OR OTHER)
DRAIN ROCK

SECTION A-A

Figure 14 RECOMMENDED GRADING AND BACKFILL PROCEDURE IF SAND IS USED AS BACKFILL

APPENDIX A

SAMPLE FIELD DATA SHEETS

CH2M HILL

STRATHCONA COUNTY RESEARCH FACILITY
LOT DRAINAGE CHARACTERISTICS STUDY
TEST INFORMATION

TEST NO.

DATE 1991 SEPTEMBER 23 TIME: START 1145 STOP 1550
ON-SITE PROJECT ENGINEER —
ON-SITE TECHNOLOGIST MERZ
OTHER PERSONNEL ON-SITE —

WEATHER

GENERAL DESCRIPTION SUNNY, SLIGHT WIND FROM SW

SITE
- WET
- ✓ DRY

TEMPERATURE

	TIME	TEMP
START		9°C
STOP		16°C

PRECIPITATION mm
TIME: START STOP

SITE CONSTRAINTS

A. SOILS TYPE
- CLAY-TILL
- ✓ SAND
- SILT
- SILTY-SAND

B. STORM EVENTS
- ✓ 4 HOUR 1:5
- 4 HOUR 1:50
- 24 HOUR 1:5
- 24 HOUR 1:25

C. SITE FORMAT
- ✓ SINGLE LOT
- SPLIT LOT

D. BACKFILL ZONE
- ✓ COMPACTED
  - POOR
  - ✓ FLAT
  - GOOD
- UNCOMPACTED
  - POOR
  - FLAT
  - GOOD
- ENGINEERED

E. SITE CONFIGURATION
- SODDED
- ✓ BARE SOIL
- TYPICAL

ROOF LEADER:
- AT WALL
- ✓ 1.5m EXTENSION
- TO STORM (SIMULATED)

SITE MEASUREMENTS

A. INFILTRATION RATES

TEST DATE
BY
RECORD NO.

COMMENTS

B. PIEZOMETER READINGS

MANUAL SEE PIEZOMETER MEASUREMENT RECORD

DATA LOGGER
TIME DOWN LOADED SEPT 24
BY WONG
RECORD NO. S01SEP24.RAW

TRANSLATION FILE NAMES:

C. RAINFALL GAUGE

TIME DOWN LOADED
BY
RECORD NO.

COMMENTS

TRANSLATION FILE NAMES:

D. PUMP ON-OFF

TIME DOWN LOADED SEP 24
BY WONG
RECORD NO. S02SEP24.RAW

TRANSLATION FILE NAMES:

SITE CHECKS

A. HYDRANT METER

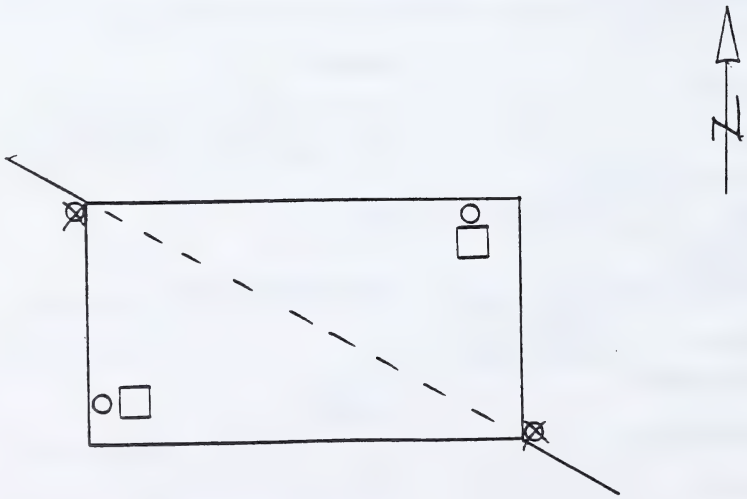
TIME	READINGS METER 1	 METER 2
1246		4506.29
1247	3837.14	
1315		4512.66
1316	3841.57	
1340		4515.71
1341	3841.11	
1427		4517.11
1429	3842.96	

B. RAINFALL MANIFOLDS

TIME CHECKED	BY
1322	MERZ
1330	
1345	
1350	
1437	
1500	
1530	

GENERAL COMMENTS ON TEST RUN (PROBLEMS, IRREGULARITIES, OBSERVATIONS)

SKETCH



CH2M HILL

STRATHCONA COUNTY RESEARCH FACILITY
LOT DRAINAGE CHARACTERISTICS STUDY
PIEZOMETER MEASUREMENT RECORD

TEST NO. ☐

DATE 1991 SEPTEMBER 23

		TIME 1155	BY MERZ	TIME 1323	BY MERZ	TIME 1427	BY MERZ	TIME	BY
PIEZOMETER NUMBER	TOP ELEVATION	READING	ELEVATION	READING	ELEVATION	READING	ELEVATION	READING	ELEVATION
7	699.606								
8	699.590								
9	699.851								
10	699.833	2.493	697.340	2.495	697.338	2.497	697336		
11	699.831								
12	699.842								
13	699.777	2.354	697.423	2.354	697.423	2.354	697.423		
14	699.720								
15	699.870								
16	699.882								
BH1	700.155								
BH1A	700.334								
BH2	700.277								
BH2A	700.325								
BH3	698.549	2557	694.992	2.556	694.993	2556	694.993		
BH3A	698.564								
BH4	698.732	2.022	696.710	2.024	696.708	2.022	696.710		
BH4A	698.598								

		TIME	BY	TIME	BY	TIME	BY	TIME	BY
PIEZOMETER NUMBER	TOP ELEVATION	READING	ELEVATION	READING	ELEVATION	READING	ELEVATION	READING	ELEVATION
7	699.606								
8	699.590								
9	699.851								
10	699.833								
11	699.831								
12	699.842								
13	699.777								
14	699.720								
15	699.870								
16	699.882								
BH1	700.155								
BH1A	700.334								
BH2	700.277								
BH2A	700.325								
BH3	698.549								
BH3A	698.564								
BH4	698.732								
BH4A	698.598								